UCRL-JC-126188 Abs

A USER FACILITY FOR RESEARCH ON FUSION SYSTEMS WITH DENSE PLASMAS

Dmitri D. Ryutov[1]

Lawrence Livermore National Laboratory, Livermore, CA 94550, USA

There exists a number of fusion systems whose dimensions can be scaled down to a few centimeters, if plasma density and confining magnetic field is raised to sufficiently high values. These systems include field-reversed configuration (FRC), spheromak, Z-pinch, multiple mirrors and some others. The fusion-grade plasma in these systems can be obtained with the energy deposited to the plasma as low as 10-100 kJ. This prompts a "user-facility" approach to the studies of this class of fusion systems. The concept of user facility was first briefly mentioned in (1). Here we present its more detailed description.

The user facility would consist of a pulsed energy source (presumably, the Marx generator), and a set of diagnostics permanently deployed at the facility site. The research groups would bring "the targets", and perform the series of experiments on the facility. Because of their small size, the "targets" would be relatively inexpensive, well within the reach of the university groups. The concept and design of the targets would be entirely the mission of the participating groups. This should have a strong favorable effect on the creative potential of the fusion research.

The main energy source could be a Marx generator with the stored energy up to 1 MJ and the pulse-length in the microsecond range. Certain pulse-shaping capacity would increase the range of possible experiments. A couple of separate energy sources with the energy content up to 100 kJ, for generating the bias magnetic field, would be desirable. The interface of the Marx generator and the load can be made very flexible.

The set of diagnostics should include optical, UV and X-ray spectroscopy, neutron diagnostics (for both DD and DT neutrons, with tritium used as a trace element), optical imaging, the X-ray backlighting. The typical time-scale of plasma processes for the aforementioned fusion systems will not be shorter than 30-50 ns. Particular research group may find possible fielding its own diagnostics.

To be more specific, we consider in more detail three possible experiments related to the FRC. The first is the study of the formation and properties of an FRC with the density ~ 10^{18} cm^{-3}, the temperature ~ 100 eV, and the magnetic field strength ~100 kG. The radius of the FRC can be 1 cm, the length 4-6 cm. The magnetic coils of the comparable size would be used for creating the bias magnetic field and for the field reversal. The total energy content in the plasma will be in this case ~ 1 kJ, the magnetic energy the magnetic energy will be of the same order of magnitude. Characteristic reconnection time is ~0.5 μs (for deuterium plasma). This sets the time-scale for the manipulations with the magnetic field (also ~ 0.5 μs) . The power level involved is ~ 1 GW, the current in the coil should be ~ 0.5 MA. All these parameters are not very demanding and can be reached even without use of the main energy source. The radiative losses do not exceed a few percent of the total power (unless the plasma is very dirty). Possibly, an independent pre-ionization system will be required.

The FRC with the aforementioned parameters will have a ratio of the plasma radius to a characteristic ion gyro-radius ~30-50, much higher than in the existing experiments and very close to the values of this parameter expected for the FRC based fusion reactor. In this experiment, the pulsed magnetic system can possibly be designed so as to survive multiple shots.

If successful, this experiment will pave the road to the second one, where the pre-formed FRC will be translated into imploding liner of the type described in (2) and then adiabatically compressed. We conceive a scenario where the hole through which the FRC will be injected will be closed early in the

---

[1] On leave from Budker Institute of Nuclear Physics, Novosibirsk, Russia

implosion, thereby trapping the FRC inside the liner. This can be reached by using the liner whose linear density (mass per unit length) on the injection end is smaller than on the rest of its length. The further adiabatic compression of the FRC by the imploding liner will create a fusion-grade plasma, with equivalent Q approaching 1. This second experiment will require the use of the main generator, with the energy delivered to the liner in the range of 100-200 kJ. The experimental assembly will now have to be replaced after every shot (for this reason, we sometimes use the word "target" to designate the experimental assembly). But since the target is be compact (with the maximum dimension not exceeding 10-15 cm), manufacturing of a few dozens of such target for one experimental campaign should be inexpensive. We imply that the experimental group will bring these targets to the user facility and "shoot" them out within a couple of weeks.

The 3D liner implosions can be used to adiabatically compress also some other closed-field-line configurations, like spheromak and even a spherical tokamak (with a central post mounted inside the liner). Although imploded spherical tokamak may not have great future as a fusion reactor, it may allow reaching new parametric domain in terms of plasma beta and thereby add substantial new information to the physics of tokamaks.

Purely radial liner implosion on a multimirror system with a dense plasma would provide favorable experimental conditions for the studies of the wall confinement (see (3)) - an issue of great importance for many pulsed systems with dense plasmas, including MAGO (4).

All in all, creation of a user facility for the studies of pulsed systems with a dense plasma would add a new dimension to fusion research. It will give an opportunity to numerous university groups to fully develop and demonstrate their creative potential. It will also be an excellent point for building up an international collaboration on innovative fusion concepts.

This work was performed under the auspices of the U.S. Department of energy by Lawrence Livermore National Laboratory under contract W-7405-Eng-48.

1. D.D. Ryutov. "Reinventing Fusion". Plenary talk at 12th American Nuclear Society Topical Meeting on the Technology of Fusion Energy, Reno, NV, June 16-20, 1996.

2. R.P. Drake, J.H. Hammer, C.W. Hartman, L.J. Perkins, D.D. Ryutov. "Submegajoule Liner Implosion of a Closed Field Line Configuration". Fusion Technology, **30**, 310 (1996).

3. D.D. Ryutov. "Controlled Thermonuclear Fusion in a Dense Quasistationary Plasma". Sov. Phys. Uspekhi, **18**, 466 (1975).

4. I.R. Lindemuth. This Conference.